Rec. West. Aust. Mus. 1992, 16(1): 79-86

Geographical and stratigraphical distribution of the echinoid *Echinometra mathaei* (Blainville) in Western Australia

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Abstract

The distribution of the camarodont echinoid *Echinometra mathaei* (Blainville, 1825) in Western Australia is discussed. Being restricted to inhabiting intertidal reef platforms, the species does not lend itself to being readily fossilised. However, its discovery in a Late Pleistocene reef limestone at Cape Burney, south of the mouth of the Greenough River, provides the first geological record of the species in Australia. The stratigraphic record of this widespread Indo-West Pacific species suggests that, like a number of other echinoids, it has undergone an easterly spread across the Indian Ocean during the Neogene and probably reached south-west Australia during the Pleistocene following the initiation of the warm water Leeuwin Current.

Introduction

The camarodont echinoid *Echinometra mathaei* (Blainville, 1825) (Figure 1A) has been described (Clark 1946) as perhaps the most abundant living echinoid in the world. Very common on coral reefs and intertidal reef flats (Negretti *et al.* 1990), *E. mathaei* has a widespread Indo-West Pacific distribution, occurring in the Gulf of Suez, Red Sea, Persian Gulf, East Africa, Bay of Bengal, Australia, Papua New Guinea, Japan, Guam, Taiwan, Solomon Islands, Indonesia, American Samoa, East China Sea and French Polynesia (Mortensen 1943).

The aim of this paper is to document the geographical distribution of the species off the Western Australian coast and to record for the first time its occurrence in the fossil record in Australia. This is of particular importance in the light of a recent paper by Negretti *et al.* (1990) who document an eastward spread of this species across the Indian Ocean during the Neogene. The presence and absence of this species from different fossil deposits in Western Australia is dependent partly on the rate of this easterly spread, but also on the occurrence of suitable lithologies for preservation.

Present distribution of *Echinometra mathaei* off the Western Australian coast

In his analysis of the distribution of echinoderms in Australia, Clark (1946) records *Echinometra mathaei* off the Western Australian coast only at Shark Bay, the Abrolhos Islands and Rottnest Island. However in the collections of the Western Australian Museum specimens are present from a wide range of localities along and off the coast (Figure 2; Table 1), ranging between latitudes 12°S and 32°S. The most southerly record of the species in Western Australia is at Rottnest Island, where it occurs in shallow burrows on wide intertidal reef platforms (Hodgkin *et al.* 1959). Individuals here tend to reach larger sizes than those occurring in tropical populations (Pearse and Phillips

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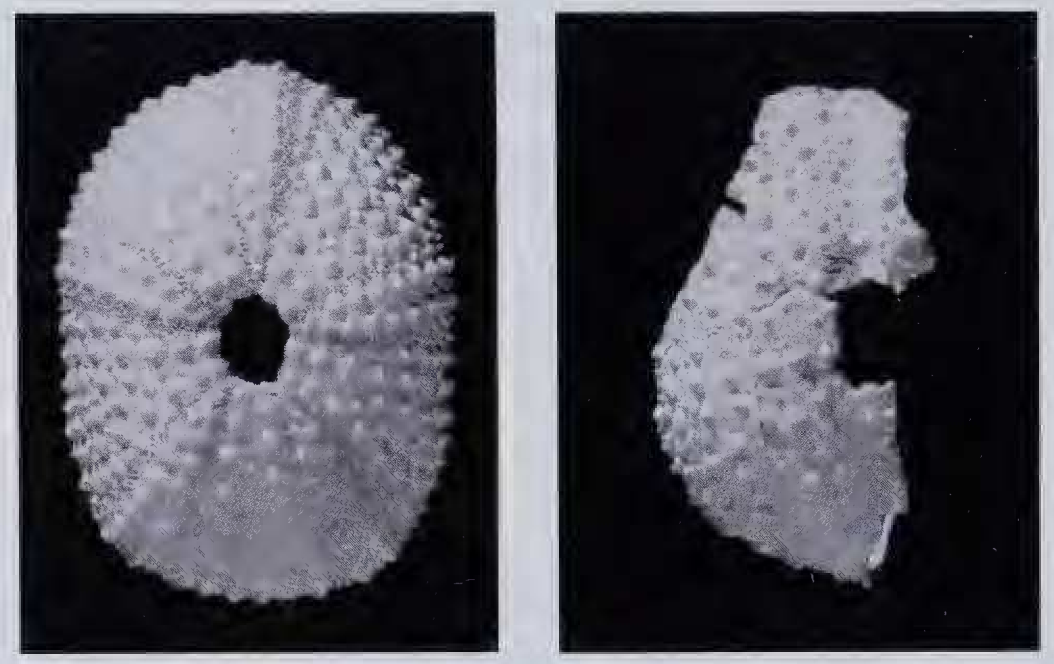

Figure 1 *Echinometra mathaei*. **A**, WAM 850-82, Recent, Barrow Island, W.A.; **B**, WAM 86.731, Late Pleistocene, Cape Burney, W.A.; both x1.

1968). The largest specimen recorded by Pearse and Phillips (1968) was an individual with a maximum test length of 67 mm. *E. mathaei* reaches a similar large size on the Houtman Abrolhos, one specimen in the collections of the Western Australian Museum (507-76) having a maximum test length of 68.5 mm. While *E. mathaei* populations off central Japan and the Gulf of Suez exhibit summer spawning periods, at Rottnest Island they reproduce throughout the year, probably on account of higher winter temperatures (Pearse and Phillips 1968).

Along the mainland coast *E. mathaei* does not extend as far south as Rottnest Island (32°00'S), the southerly most mainland coastal record being of a single specimen from Port Gregory, some 450 km further north (28° 12'S). *E. mathaei* has also been found at Shark Bay (off Dorre Island); in the region of North West Cape at Coral Bay, Ningaloo Reef and Exmouth Gulf; around Barrow Island; and in the Dampier Archipelago region at Kendrew, Delambre and Rosemary Islands. However, *E. mathaei* has not been found on the nearshore Kimberley coast or reefs (L.M. Marsh, pers. comm.). Further off the coast the species has been collected from the Houtman Abrolhos (Teichert 1947), Rowley Shoals, Scott and Seringapatam Reefs (Marsh 1986), Cartier Island and Ashmore Reef (Table 1). Further out in the Indian Ocean *E. mathaei* has been found at Christmas Island and Cocos Keeling Islands.

Clark (1946) was surprised that he found only one record of the species from the northern Australian coast, a specimen from the Gulf of Carpentaria. The extent of the range of *E. mathaei* off the northern coast is not known. However, it is known to extend down the Queensland coast to Lord Howe Island. Specimens are present in the Western Australian Museum collections from Darnley, Murray and Yorke Islands in the Torres Strait; Green, Heron, Lizard and Reef Hook Islands in the Great Barrier Reef, Queensland, as well as from Lord Howe Island. Dakin (1987) records it as far south on the mainland as Coffs Harbour, New South Wales. Consequently, it is likely that wherever there is a suitable reefal or rocky habitat, in a region of moderately high hydrodynamic activity, *Echinometra mathaei* can be expected to be found, from Lord Howe Island on the eastern coast, around the northern coast of Australia, and south down the western coast to Rottnest Island.

Fossil distribution of *Echinometra mathaei* in Western Australia

In September 1985 Mr Alan Rowe collected two specimens (WAM 86.504, 86.731) of *Echinometra mathaei* from a fossil reef deposit in low cliffs at Cape Burney, about 200 metres south of the mouth of the Greenough River (28°52'S 114°38'E), near Geraldton. Although both specimens are incomplete (Figure 1B) there is no doubt that they belong to the living species. Like the living specimens from Rottnest Island and the Houtman Abrolhos, these two specimens are both relatively large, one (WAM 86.731: Figure 1B) probably having had an original test length in the region of about 70 mm.

The outcrop from which the specimens were collected is about 2m above present day sea level and forms part of the Tamala Limestone. The unit probably formed as a small, offshore patch reef over a pre-exisiting calcarenite (G.W. Kendrick, pers. comm.) and closely resembles the contemporaneous Rottnest Limestone that outcrops on the southern shores of Rottnest Island at Fairbridge Bluff. From its geological setting, the nature of the accompanying mollusc fauna and its degree of weathering, it is likely that the Cape Burney deposit was one of a number formed during the Late Pleistocene along the western Australian coast (Teichert 1947, 1967; Fairbridge 1954; Playford 1988; Kendrick *et al.* 1991), probably during the Last Interglacial (Oxygen Isotope Substage 5e)(G.W. Kendrick, pers. comm.). In addition to *E. mathaei* two other echinoid species occur in this unit: *Protenaster australis* (McNamara 1985) and *Phyllacanthus irregularis*. The former species is represented by three specimens, the latter by a single interambualcral plate and a number of radioles. *Phyllacanthus irregularis* has hitherto not been reported from the fossil record.

A number of Western Australian formations that range in age from Early Miocene to Middle Pleistocene contain reasonably large echinoid faunas. However despite extensive searching over the last decade *Echinometra* has not been found in any of these deposits. For instance material collected from a large number of boreholes in the Perth Basin that derive from shallow marine deposits of the Pliocene-Early Pleistocene Ascot Formation (Kendrick *et al.* 1991) have yielded abundant echinoid remains, in particular species of *Echinocyamus* and *Ammotrophus*. Yet no evidence of *Echinometra mathaei* has been found. Similarly, it has not been found in the Middle Pleistocene Carbla Oolite that outcrops in Shark Bay (Logan *et al.* 1970) despite the presence of shallow water echinoids such as *Breynia desorii* Gray and *Peronella ricta* Gregory. However, these

Table 1 The recent distribution of *Echinometra mathaei* around Western Australia

Lat.(S) / Long.(E)	Locality	No. of specimens
10°30' 105°35'	Christmas Island	35
12°05' 96°55'	Cocos Keeling Islands	4
12°15' 123°00'	Ashmore Reef	3
12°32' 123°33'	Cartier Island	1
14°05' 122°11'	Scott and Seringapatam Reefs	2
17°30' 119°00'	Rowley Shoals	5
20°33' 116°32'	Dampier Archipelago	7
20°46' 115°24'	Barrow Island	8
21°47' 114°10'	North West Cape	4
22°05' 114°15'	Exmouth Gulf	1
22°40' 113°40'	Ningaloo Reef	22
23°07' 113°45'	Coral Bay	4
25°00' 113°07'	Dorre Island, Shark Bay	5
28°12' 114°15'	Port Gregory	1
28°35' 113°40'	Houtman Abrolhos	31
32°00' 115°30'	Rottnest Island	11

infaunal burrowers would not have shared the same habitat as *E. mathaei*. Coral-dominated assemblages from the Shark Bay Pleistocene, within which the species might be expected to occur, have not been adequately collected. The absence of *E. mathaei* from some of these older units may reflect, in part, the lack of a suitable habitat for the species. Its absence, despite extensive searching, from the Late Pleistocene Rottnest Limestone on Rottnest Island suggests that during the Late Pleistocene it did not range as far south as it does today on the offshore islands. However, along the mainland coast at this time it extended further south that it does today.

Its occurrence with *Protenaster australis* at Cape Burney is interesting, because today the only site at which the tropical *E. mathaei* occurs with the southern Australian *P. australis* is on Rottnest Island. While the Late Pleistocene occurrence of *E. mathaei* at Cape Burney is the southerly most known record of the species along the mainland coast, this site represents the most northerly known occurrence of *P. australis*. The slight overlap in geographic ranges of these two species on the mainland coast in the Late Pleistocene is in contrast to the present day situation, with the ranges of the two being widely disjunct, the range of *P. australis* having contracted to the south.

The shift from predominantly siliciclastic to mainly carbonate sedimentation along the inner shelf of southwestern Australia during the Middle Pleistocene (Kendrick *et al.* 1990), as represented by the formation of the Tamala Limestone, was possibly associated with a current/temperature regime that ought to have been favourable to the presence in local waters of *E. mathaei*, at least during transgressive episodes. This has been interpreted as reflecting the initiation of the warm water Leeuwin Current (Kendrick *et al.* 1991) during the Middle Pleistocene. Severe oceanic cooling during terminal Pleistocene Stage 2 in the south-east Indian Ocean (Prell *et al.* 1980) probably caused a

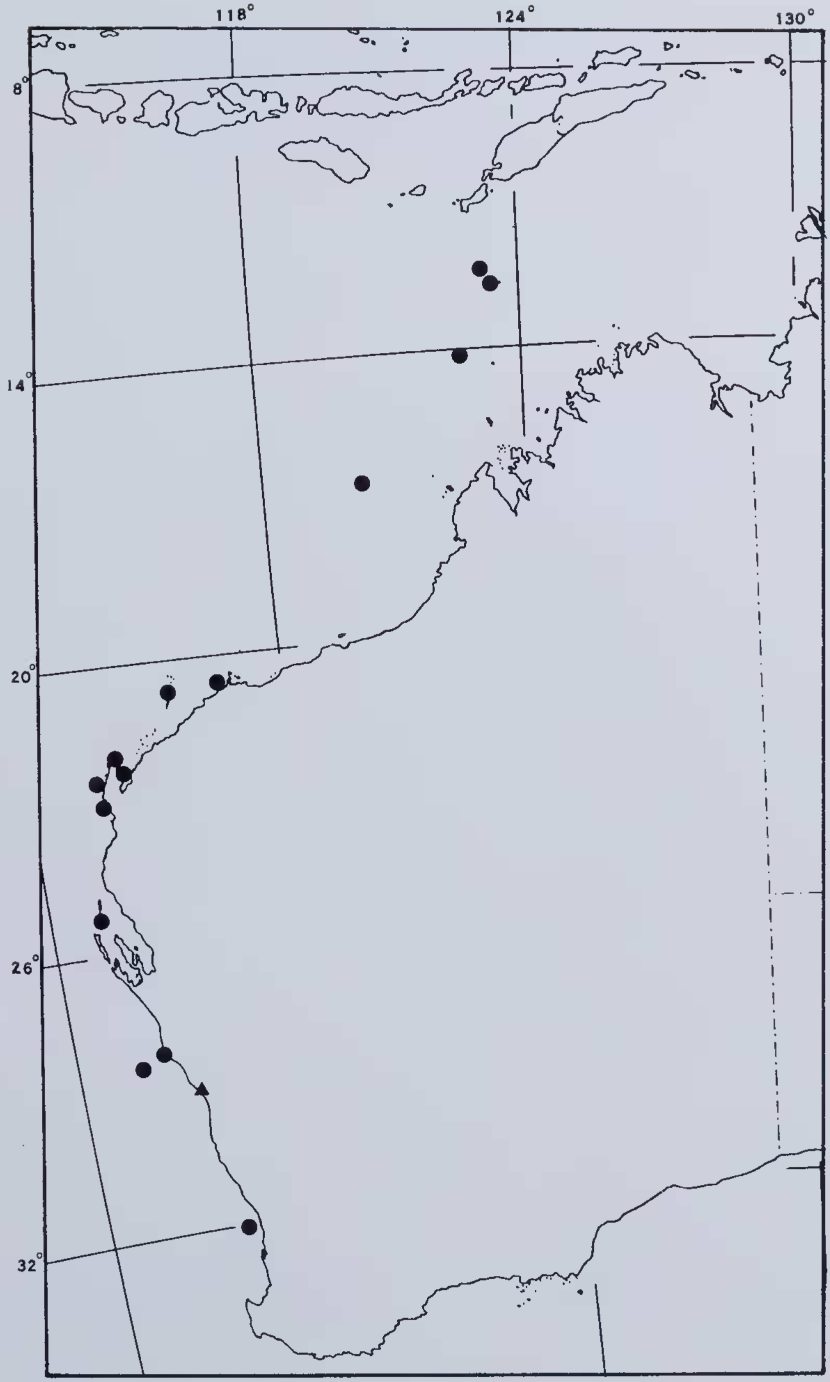

Figure 2 Map of Western Australia showing the distribution of living (●) and fossil (▲) *Echinometra mathaei.*

Table 2 Times of known occurrence of *Echinometra mathaei* in the Mediterranean Sea, Red Sea and eastern Indian Ocean.

Mediterranean Sea[1]	Red Sea[2]	Eastern Indian Ocean[3]
Miocene	Miocene	—
—	Pliocene	—
—	Pleistocene	Pleistocene
—	Recent	Recent

[1] Negretti *et al.* (1990); [2] Ali 1985; Brighton 1931; [3] W.A. Museum collections

contraction of range toward the equator of temperature-sensitive, tropical and subtropical species, such as *E. mathaei*. If this were the case, then the modern stocks of this, and other such species, that now inhabit extra-tropical waters, would represent post-Pleistocene re-colonisation from the north, presumably as plankton via the Leeuwin Current. It is known that *E. mathaei* is a planktotrophic species and, in this part of Western Australia, breeds all year (Pearse and Phillips 1968). The absence of *E. mathaei* from the Late Pleistocene Rottnest Limestone, despite it being a typical lithology for the species, suggests that at this time the species had spread no further south than the mouth of the Greenough River.

The present day concentration of *E. mathaei* at the West End of Rottnest Island, and its apparent absence from the opposite end, is considered to reflect the effect of the Leeuwin Current. NAOO satellite imagery of the Leeuwin Current (see cover photograph of *The Leeuwin Current: an influence on the coastal climate and marine life of Western Australia*: Jl. Roy. Soc. W.A., vol. 74) clearly shows a tongue of the Leeuwin Current extending past the western end of Rottnest Island, and cooler water of the West Australian Current wedging north between this tongue of the Leeuwin Current and the coastline. It is probably this cooler, near coastal water originating from northerly flowing cooler currents, that is responsible for the absence of *E. mathaei* along coastal shorelines between Perth and Port Gregory.

Neogene dispersal of *Echinometra mathaei* across the Indian Ocean

In a recent restudy of *Echinometra miocenica* Loriol from the Early Miocene of southern France, Negretti *et al.* (1990) found no evidence to support the view that this species was any different from the living species *E. mathaei*. Consequently they placed *E. miocenica* in synonymy with *E. mathaei*. Thus this species has existed for about 17 million years. However, of particular interest is evidence from the fossil record that indicates a changing distribution of this species through the Neogene.

The earliest, Early Miocene, specimens of *E. mathaei* occur in the south of France at Sériège, Hérault and in northern Sardinia in the Mediterranean Sea, and along the Suez Gulf and Red Sea coasts of Egypt (Negretti *et al.* 1990). However, as Negretti *et al.* (1990) have reported, the range of *E. mathaei* retracted eastwards into the Pliocene as it became locally extinct in the Mediterranean Sea at the time of the Messinien crisis during the Late Miocene. There is ample evidence, however, that it persisted in the Red Sea, having been recorded in Pliocene and Pleistocene deposits at Mersa Alam along the Red Sea coast of Egypt (Ali 1985) and in the Pleistocene of Farsan Island, south of the Red Sea (Brighton 1931).

Its appearance in Late Pleistocene deposits at the eastern end of the Indian Ocean implies that between the Miocene and Pleistocene it spread eastwards from its centre of origin in the Mediterranean region to the eastern Indian Ocean and into the western Pacific (Table 2). Negretti *et al.* (1990) report a similar pattern of migration for *Echinoneus cyclostomus* through the Neogene. McKinney *et al.* (1992) have likewise described the same eastwards migration of nine genera of echinoids across the Indian Ocean during the Tertiary.

Conclusions

The presence of *E. mathaei* at Cape Burney during the Late Pleistocene, outside of its modern day range along the coast, is probably indicative of past oscillations in the strength of the Leeuwin Current, as the present day geographical distribution of the species appears to be closely linked to the course of the Leeuwin Current. It has been suggested (Collins *et al.* 1991) that the existence of Late Pleistocene coral reefs on the Houtman Abrolhos, at Cape Burney and on Rottnest Island reflects a period of more vigorous Leeuwin Current activity at that time than at present (Collins *et al.* 1991). While it could be argued that the apparent absence of *E. mathaei* in the Rottnest Limestone, and the more northerly extension of the cool water spatangoid *P. australis* during the Late Pleistocene implies that the intensity of the Leeuwin Current was less then than it is now off the coast, the existence of Late Pleistocene coral reefs on Rottnest Island does not support this view. The presence of *E. mathaei* at Cape Burney during the Late Pleistocene, argues for perhaps a stronger influence of the Leeuwin current along the mainland coast during the Late Pleistocene, because today along the mainland coast *E. mathaei* extends only as far south as Port Gregory, some 80 km north of Cape Burney.

It is likely that *E. mathaei* would not have existed this far south during glacial stages 2,4, and 6, when sea temperatures were appreciably lower than at present (G.W. Kendrick pers. comm.). It probably persisted farther north in warmer, tropical waters at these times. The initiation of the Leeuwin Current, probably in the Middle Pleistocene (Kendrick *et al.* 1991) may well have been the event that allowed *E. mathaei* to extend south from its normal tropical range, down the south-west Australian coast. Initially, during the Late Pleistocene, it appears to have only reached as far south as Cape Burney (28° 52'S). Following its probably northwards contraction of range during the last glacial stage, it has spread further south with the Holocene rejuvenation of the Leeuwin Current, reaching Rottnest Island (32° S). The geographical range of the species is therefore likely to have been appreciably different during periods of transgressions from its range during regressions.

Acknowledgements

I would like to thank Mr Alan Rowe for kindly donating the fossil specimens that he collected to the Western Australian Museum. I greatly appreciate the constructive comments provided to me by Mr George Kendrick and Mrs Loisette Marsh. I am also grateful to Mrs Marsh for allowing me access to collections in her care. Thanks also to Ms Kris Brimmell for the photographs. Dr Patrick Hesp kindly provided logistical support on Rottnest Island.

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Received 7 February 1991 Accepted 26 May 1992 Published 18 September 1992